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Barge Loading Facilities: Summary Report for Technical Support in Development of a Revised Ozone State Implementation Plan for Memphis, Tennessee

Pacific Environmental Services, Inc.
Durham, NC

Prepared for

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REPORT

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PACIFIC ENVIRONMENTAL SERVICES, INC.

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BARGE LOADING FACILITIES

SUMMARY REPORT

FOR

TECHNICAL SUPPORT IN DEVELOPMENT
OF A REVISED OZONE STATE
IMPLEMENTATION PLAN FOR
MEMPHIS, TENNESSEE

Mr. Ron McHenry - Project Officer
U.S. Environmental Protection Agency
Region IV
EPA Contract No. 68-02-3887
Assignment No. 13

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DISCLAIMER

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1.0 INTRODUCTION AND SUMMARY

This document presents information on emissions of volatile organic compounds (VOC's) from barge loading facilities in Shelby County, Tennessee. Information is presented on the process, emissions, emission control techniques, and the cost of reducing emissions based on information from a variety of sources. These sources include: an inspection of a barge loading facility, U.S. Environmental Protection Agency (EPA) documents, technical literature, telephone communications with a representative of the MAPCO barge loading facility, and meetings with EPA personnel.

For barge loading facilities, reasonably available control technology (RACT) is determined to be in place. RACT is defined as the lowest emission limit that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility. It may require technology that has been applied to similar, though not necessarily identical, source categories. It is not intended that extensive research and development be conducted before a given control technology can be applied to the source. This does not, however, preclude requiring a short term evaluation program to permit the application of a given technology to a particular source. The latter effort is an appropriate technology forcing aspect of RACT.

The control techniques investigated in this report reflect ongoing research to reduce VOC emissions from barge loading facilities. Control techniques include vapor capture systems and processing of these vapors in a control device. The control devices themselves (i.e., carbon adsorbers, refrigeration units, and lean oil absorbers) are in widespread use in many industries in the United States. The following chapters provide a technical description of each system as well as detailed cost estimates and expected performance levels of these systems. The basis for this information is a status report for demonstration of vapor control technology for gasoline loading of barges. This work was performed by EPA and its contractor (MSA Research Corporation), and involved investigation of a theoretical vapor control system. However, since this system was never physically assembled, it

cannot be considered a workable control recovery system. At present, there is one shoreside vapor control system. Marion Oil Company of Mobile, Alabama, has installed a vapor control system using incineration.[1] However, they have not found a barge that can use their device. This is not considered to be a permanent, workable system at present. There are vapor control systems on a few ocean-going barges, but these systems are not feasible to adaptation by river barges due to size differences and costs. Additionally, control technology transfer from existing vapor control systems at gasoline bulk terminals is not technologically feasible due to safety considerations. These considerations arise from the fact that gasoline vapors from barges enter the explosive concentration range, a situation not found in gasoline bulk terminals. For these reasons, RACT is determined to be in place.

1.1 REFERENCES

1. MSA Research Corporation, "Demonstration of Vapor Control Technology for Gasoline Loading of Barges." U.S. Environmental Protection Agency, Contract No. 68-02-3657. August 1984.

2.0 SOURCES OF VOC EMISSIONS

2.1 FACILITY DESCRIPTION

Barge loading facilities are typically adjacent to a refinery owned by the same company with one or more docks used for unloading crude and loading refined petroleum products. Each dock may have several lines to transfer petroleum liquids, each dedicated to a specific service, for example, unleaded gasoline, #6 fuel oil, etc. Generally, finished products are pumped from refinery storage tanks to barges. Occasionally, gasoline may be pumped from a barge to a refinery storage tank as part of area cooperative efforts to minimize distribution costs. It is assumed that gasoline terminals use submerged fill pipes for loading barges to avoid unnecessary splashing and to minimize evaporative losses of product. Because docks employ dedicated transfer lines, they can become crowded with piping, valves, hoses and loading arms. Thus, the physical size of a vapor transfer system may be a significant feature. This fact will tend to be specific to docks, therefore, size considerations of these systems have not been taken into account.

2.2 PROCESS DESCRIPTION

Barge loading proceeds by positioning a dedicated line fill hose near the barge loading pipe. A crane or "horse" equipped with a hook raises the hose into position, blind flanges are removed from both the fill hose and the barge fill pipe, and the hose and pipe are coupled. As the barge takes on product, it gradually rests lower into the water (river barges typically hold 20,000 to 30,000 barrels while ocean barges are considerably larger). At the onset of barge loading, ullage caps to the compartments being filled are opened and the load level is monitored, usually through small (3-inch diameter) ports with a calibrated rod.[1] Opening the ullage caps allows displacement of vapors to relieve pressure on the barge loading system. Since vapors are released through ullage caps rather than a pressure release valve, over-pressurization due to a defective valve is avoided. Ullage caps and metering ports are closed following compartment filling.

Initial filling is accomplished by gravity feed. All flow valves are opened and the product is allowed to flow into the barge. Once

the system is functioning properly, a loading pump is started. When the tank level approaches full, the rate of pumping is gradually slowed to prevent a "water hammer" (i.e., a sudden pressure front) effect. After loading side valves are closed, the product remaining in the lines is drained into the barge. The hose pipe connection is then broken and the respective blind flanges are attached over a drip tank. The Coast Guard requires a drip tank to catch any spillage.

2.3 VOC EMISSIONS

Emissions of VOC are composed primarily of the vapors displaced during barge loading. Other potential sources of VOC emissions include equipment leaks and evaporative loss from both the dock facility and the barge. This section discusses emissions from the barge and from the loading and unloading dock.

2.3.1 Barge Emissions

Emissions that occur during barge loading comprise the largest portion of emissions from barge loading facilities. In the absence of any controls, displacement gases during barge loading are released to the atmosphere through compartment ullage caps and metering ports. These lost gases represent the largest source of emissions from barge loading facilities. The magnitude of the loading emissions is mainly a function of the type of petroleum liquids transferred to or from the barge and the throughput.

Emissions from barge displacement gases at a single facility may exceed 300 Mg/year (330 tons/year). Table 2-1 presents the basis for estimating emissions from displacement gases from an uncleaned, dedicated eight-compartment barge. For gasoline, a hydrocarbon vapor content of 18 percent was used.[2] At this concentration and loading rate, an emission factor of 0.00048 Mg/1000 l (4 lbs/1000 gal) gasoline loaded is used.[3] Total emissions for barge loading are estimated at 315 Mg per year with gasoline being the predominant source, accounting for over 99 percent of the example presented in Table 2-1.

2.3.2 Dock Emissions

Potential VOC emission sources associated with barge loading docks include the equipment components associated with the transport of petroleum liquid (e.g., valves, pumps, and flanges) and the drip tank in place to catch any spillage from transfer hoses. Typical practice at

TABLE 2-1. EMISSION FACTORS FOR BARGE LOADING

Component	Emission Factor[a]	Throughput[b]	Total Emissions
gasoline	0.00048 Mg/1000 l 4 lbs/1000 gal	655 x 10^6 l/yr 173 x 10^6 gal/yr	314 Mg/yr 346 tons/yr
#2 diesel fuel	1.44 x 10^{-6} Mg/1000 l 0.012 lbs/1000 gal	655 x 10^6 l/yr 173 x 10^6 gal/yr	0.94 Mg/yr 1 ton/yr
#6 fuel oil	1.1 x 10^{-8} Mg/1000 l 0.00009 lbs/1000 gal	91 x 10^6 l/yr 24 x 10^6 gal/yr	0.00101 Mg/yr 0.001 ton/yr

[a]Reference 3.

[b]Throughput for barge loading facility in Shelby County. Reference 4.

barge loading facilities is to repair any piece of equipment observed dripping petroleum liquids. However, emissions of VOC through pump packing glands, valve stem seals, or flange gaskets may occur unnoticed through visual detection. Table 2-2 presents the basis for a VOC emission estimate from a typical loading dock at less than 10 Mg/yr. This estimate does not include emissions of VOC from petroleum liquids contained in the dock drip tank. Assuming that any contained spillage would be immediately returned to a storage tank, these emissions would be negligible.

TABLE 2-2. DOCK EMISSION ESTIMATES

Component Type	Service[a]	Number of Components[b]	Emission per Component (kg/day)[c]	Annual Emission Mg/yr	Annual Emission tons/yr
pumps	light liquid	1[d]	2.69	1.0	1.1
valves	light liquid	25	0.640	5.8	6.4
	heavy liquid	25	0.00499	0.045	0.05
flanges	all	50	0.00698	0.099	0.11
				6.94	7.66

[a] Light liquid is defined as having a Reid vapor pressure greater than kerosene. Heavy liquid is defined as having a Reid vapor pressure less than or equal to kerosene.

[b] Reference 5.

[c] Reference 6.

[d] Each barge loading dock has one pump to return any petroleum liquid spillage from the drip tank to product or crude storage. Barges are also equipped with at least one pump. However, since barges are infrequently at a dock facility, dock emissions do not include emissions from the barge transfer pump or other equipment components associated with a barge.

2.4 REFERENCES

1. Telecon. Sink, M., Pacific Environmental Services, Inc., with Ramsey, L., MAPCO Petroleum Inc. Determining load level of barges. March 11, 1985.

2. Compilation of Air Pollutant Emission Factors. Section 4.4-8. U.S. Environmental Protection Agency. Research Triangle Park, N.C. July 1979.

3. Environmental Protection Agency, "Control Technology Evaluation for Gasoline Loading of Barges," EPA Report No. EPA-600/2-79-069, Environmental Protection Agency, Research Triangle Park, N.C. 1979.

4. Telephone Conversation. Sink, M., Pacific Environmental Services, Inc., with Upton, P., MAPCO. Throughputs for a typical loading dock. March 6, 1985.

5. Memorandum. Rhoads, T.W., and D.G. Cole, Pacific Environmental Services, Inc., to J. Ronnie McHenry, U.S. EPA. Trip Report. MAPCO Petroleum, Inc. February 8, 1985.

6. VOC Fugitive Emissions in Petroleum Refining Industry - Background Information Document for Proposed Standards. U.S. Environmental Protection Agency, Research Triangle Park, N.C. Publication No. EPA-450/3-81-015a. January 1982.

3.0 EMISSION CONTROL TECHNIQUES

As discussed in Chapter 2, the largest single source of VOC emissions from barge loading facilities is the displacement gases that escape through open ullage caps and metering ports during compartment filling. Significant reductions of VOC emissions (85 percent or better) may be accomplished, however, through use of a vapor control recovery system.[1] The control alternatives considered include a vapor collection system venting to a vapor recovery unit (either carbon adsorption, refrigeration, or lean-oil absorption). A schematic diagram of a vapor collection system is shown in Figure 3-1. Barge modifications are necessary for retrofit applications as shown in Figure 3-2. At present, there is no known permanent dockside vapor control system in use.[2] Control technology transfer from gasoline bulk terminals, which utilize vapor recovery systems, is presently not feasible due to safety considerations. During barge loading, gasoline vapors from barges enter the explosive concentration range. This hazard, not found in loading gasoline tank trucks, must be considered in designing and implementing any vapor control recovery system. The control methods investigated in this report do not represent a permanent, workable application of a control system. Control techniques were investigated in the event that future technological changes make their implementation feasible.

Add-on control techniques investigated include: activated carbon, refrigeration, and lean-oil absorption. These techniques are discussed in Sections 3.1, 3.2, and 3.3, respectively. Other points of VOC emissions from barges and loading docks can be minimized through good operating practices as discussed in Section 3.4.

3.1 ACTIVATED CARBON BED

The typical activated carbon unit will generally have two or more adsorption beds. One or more beds collects vapors while one bed is regenerated. A schematic of a typical system is shown in Figure 3-3. During adsorption, hydrocarbons in the air stream penetrate the carbon particles and are retained. The ability of activated carbon to retain hydrocarbons depends on molecular size, vapor pressure and temperature. Larger molecules are adsorbed more strongly than smaller ones, but are also more difficult to desorb. In general, methane and ethane, which are

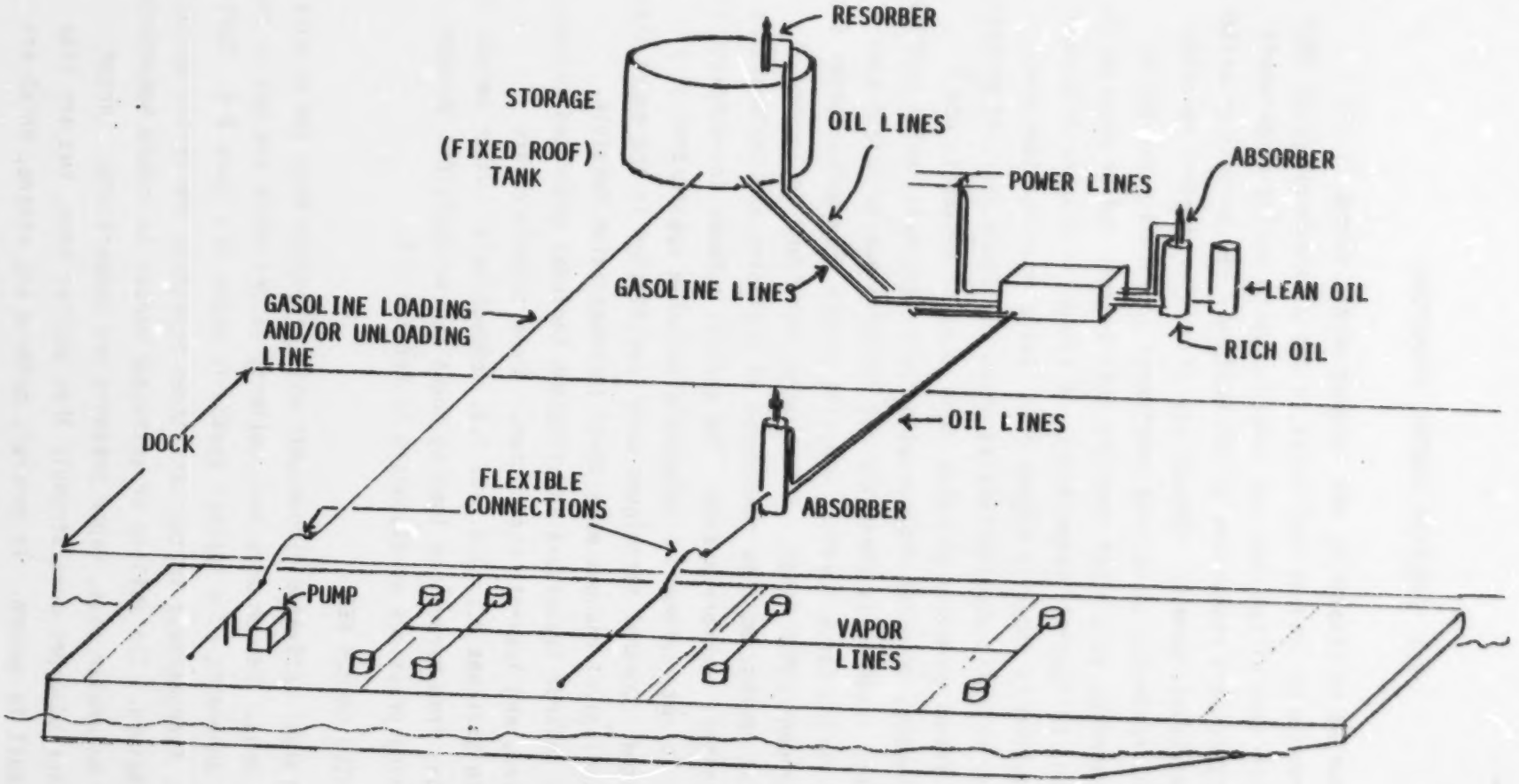

Figure 3-1. Fixed Vapor Collection System[1]

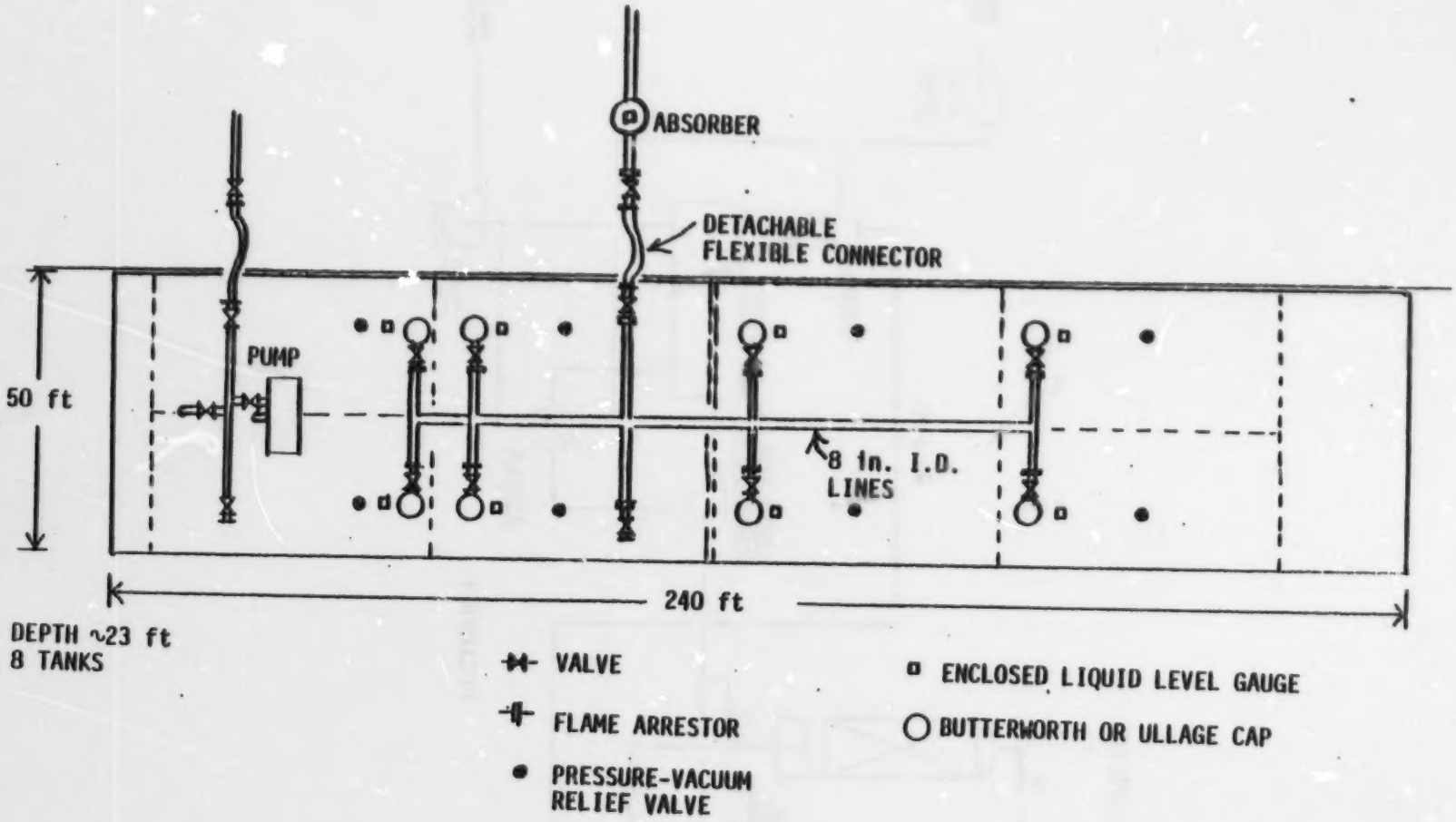

Figure 3-2. Plan View of Barge Modifications[1]

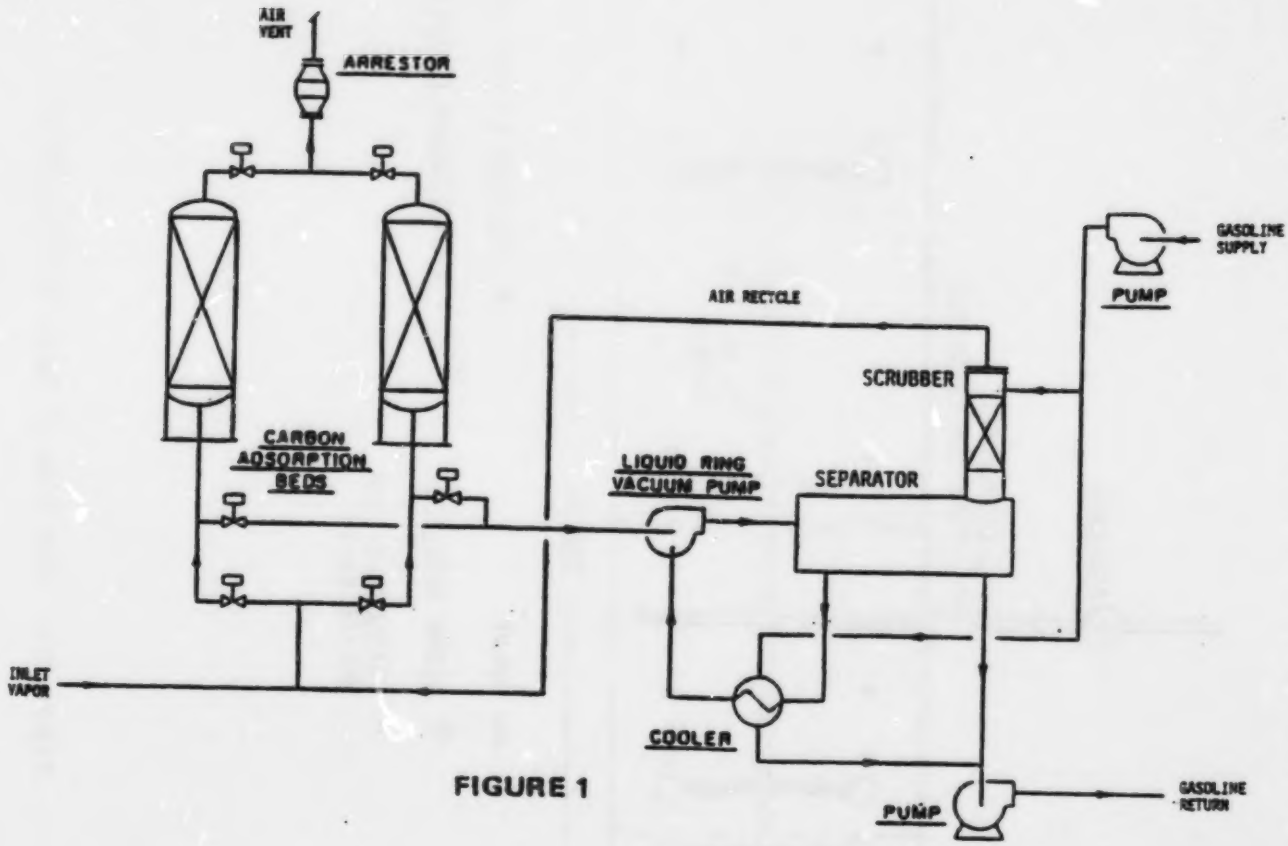

FIGURE 1

Figure 3-3. Carbon Adsorption System.[1]

classified as non-VOC hydrocarbons, are too weakly adsorbed for carbon beds to be effectively used in their recovery, while molecules larger than octane are difficult to desorb. Hence, the effective range for the carbon bed is from propane to octane.[1]

The bed can be regenerated by desorbing the hydrocarbons. This is done usually by increasing carbon bed temperature (steam injection) or by reducing the vapor pressure (inducing a vacuum). Bed regeneration is most commonly done by steam injection or indirect heating, but inducing a vacuum results in better regeneration of the bed. However, this is generally more costly than steam injection.

3.2 REFRIGERATION UNIT

Refrigeration vapor control utilizes the equilibrium vapor-liquid balance to condense hydrocarbon vapors out of a gaseous stream. This is accomplished by cooling the gas mixture to as low as -73°C (-100°F). At this temperature, all hydrocarbon gases except methane and ethane condense and drain out as liquids.

Gasoline air-vapor mixtures invariably contain water vapor; because of this, the gases are first cooled to about 1°C (34°F) to remove as much water as possible. The gases are then cooled further to about -73°C (-100°F) where hydrocarbon vapors condense into a liquid stream (see Figure 3-4).

One of the advantages of a refrigeration system is that the heavier hydrocarbons condense more easily and form a liquid which readily absorbs lighter hydrocarbon vapors. Most condensers are designed to take advantage of this by using counter-current streams of gas and liquid. The refrigerant material enters the bottom of the condenser at its coldest temperature while the gas stream enters at the top. A liquid film (from the heavier hydrocarbons) forms at the top of the condenser and as it moves down, absorbs the lighter, more volatile hydrocarbon components. The net result is that the residual vapor concentration is considerably lower than that predicted solely on the basis of saturated vapor pressures. A disadvantage of the refrigeration system is that it requires a relatively large amount of energy to operate.

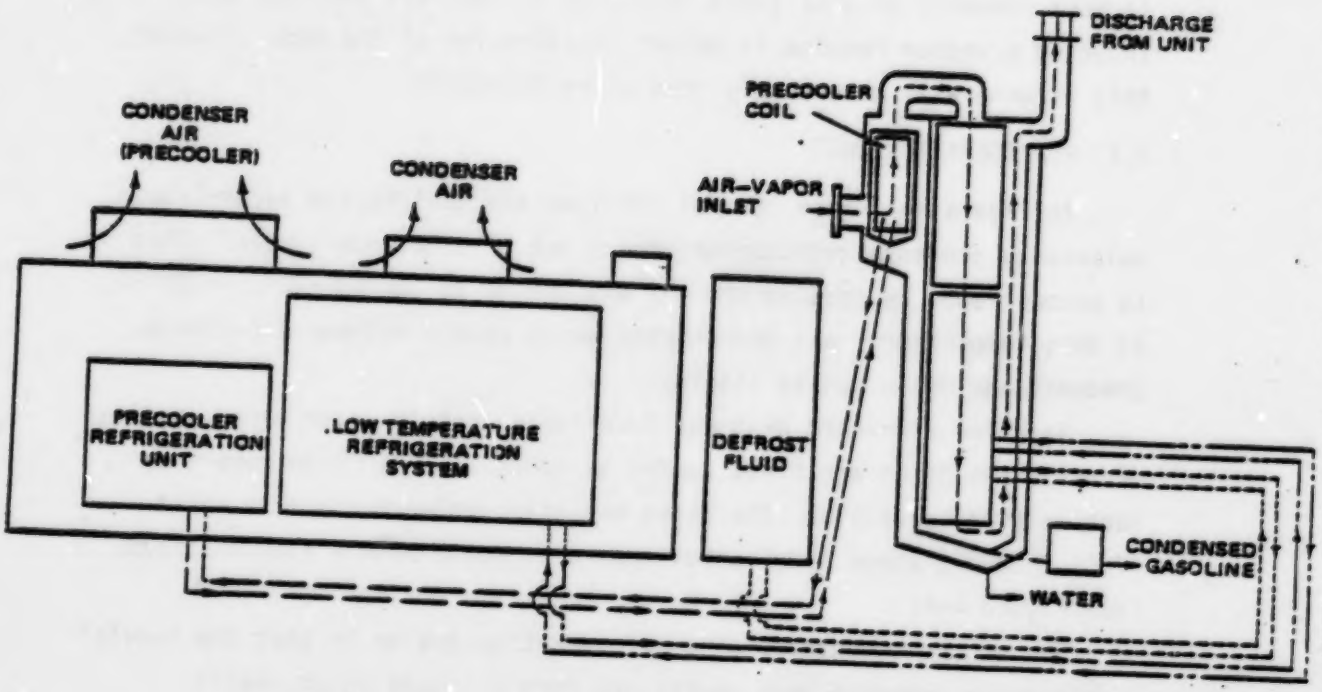

Figure 3-4. Schematic Diagram of Refrigeration Unit.[1]

3.3 LEAN-OIL ABSORPTION

Lean-oil absorption uses cooled, lean fuel oil (usually Diesel #2) in a scrubber to remove hydrocarbons from a gas stream. As with carbon adsorption and refrigeration, methane, ethane, and some propane will pass through the system and vent to the atmosphere. Butane and heavier hydrocarbons are absorbed with increasing effectiveness. After absorbing hydrocarbons the enriched oil is pumped to a rich-oil tank.

Regeneration occurs by heating the oil to 93°C (200°F) at a low absolute pressure to vaporize the hydrocarbons. The stripped oil is then: (1) cooled to condense the vapors (similar to the refrigeration technique), see Figure 3-5; or (2) compressed to 400-500 mm Hg and absorbed into a gasoline stream in a packed column, see Figure 3-6.

The basic effectiveness of this system depends on the amount of oil versus the amount of gasoline passed through the scrubber in addition to the purity and temperature of the diesel oil. Economical operation is achieved by adjusting the lean oil flow rate according to the concentration of hydrocarbons in the incoming vapor.

3.4 OPERATING PRACTICES

Emissions of VOC from leaking equipment components can be stopped in most instances through simple repair procedures such as tightening of packing glands. Simple repair can usually be accomplished without taking the leaking equipment component out of service, however, successful repair will occasionally necessitate isolating a component for repair. Valve and pump packing usually becomes brittle with age and must be replaced to ensure the leak-tight integrity of the seal.

Other good operating practices include the immediate return of any petroleum liquid spillage from drip tanks to a storage tank. Petroleum liquids retained in spillage tanks represent significant sources of evaporative loss to the atmosphere, therefore, VOC emissions are reduced in proportion to the reduction in time between a spill occurrence and the time at which the spilled liquids are returned to a storage vessel.

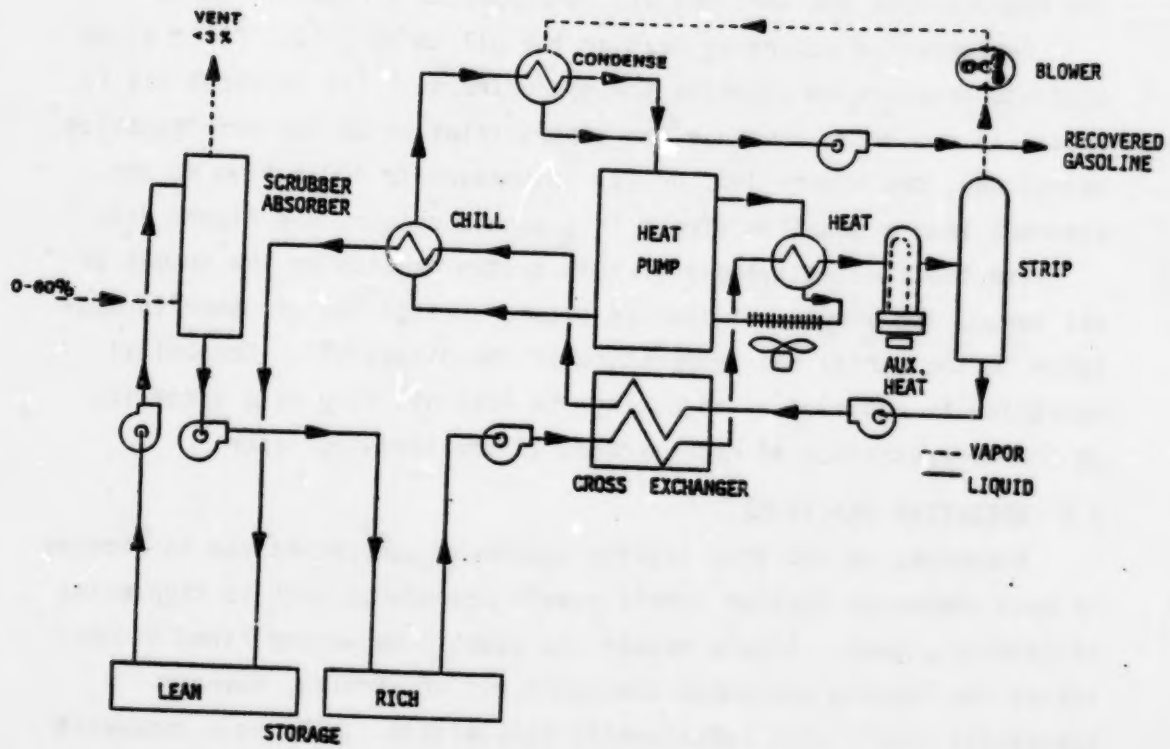

Figure 3-5. Lean-Oil Absorber with Condenser[1]

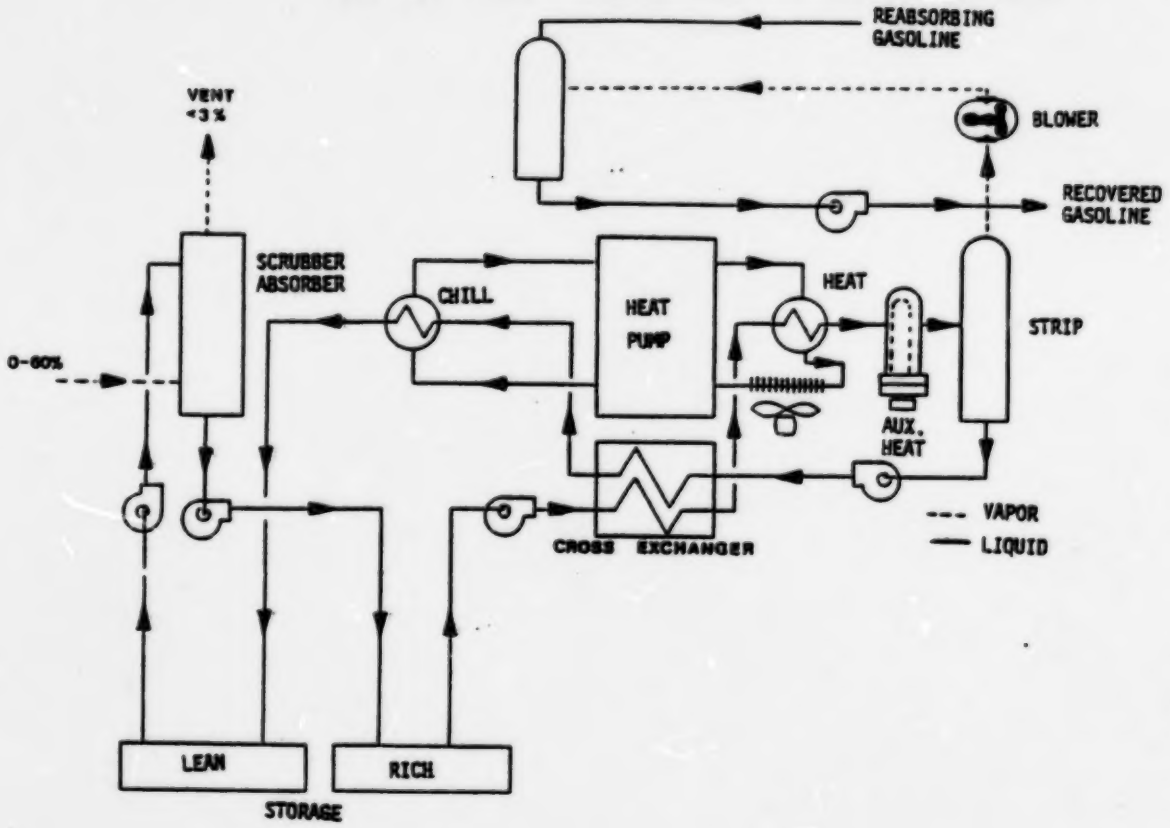

Figure 3-6. Lean-Oil Absorber with Compressor[1]

3.5 REFERENCES

1. MSA Research Corporation, "Demonstration of Vapor Control Technology for Gasoline Loading of Barges." U.S. Environmental Protection Agency, Contract No. 68-02-3141. December 1979.

2. Memorandum from Sink, M., Pacific Environmental Services, Inc. to Project File PES Project No. 0727. Background information for gasoline loading of river barges. April 24, 1985.

4.0 ENVIRONMENTAL ANALYSIS OF RACT

This chapter discusses the environmental impacts that would result from implementing reasonably available control technology. Section 4.1 presents RACT recommendations for barge loading facilities and the impacts associated with implementing RACT. Section 4.2 presents a quantitative assessment of implementing control techniques demonstrated in other types of facilities transferring petroleum liquids, but not yet demonstrated for barge loading.

4.1 REASONABLY AVAILABLE CONTROL TECHNOLOGY (RACT) PROCEDURES

RACT procedures include weekly visual checking of pumps, valves, and flanges on docks. Barge or dock equipment components that appear to be leaking on the basis of sight, smell, or sound should be promptly repaired as soon as possible with a first attempt at repair within 5 calendar days and successful repair within 15 calendar days. Any spillage that results from barge loading operations should also be immediately stored in a closed storage container or returned to a closed storage tank.

Since there is no demonstrated vapor control system for river barges, RACT for barge loading facilities in Shelby County is judged to be in-place. Therefore, no impact on air, water, solid waste or energy is associated with implementation of RACT.

4.2 UNDEMONSTRATED TECHNOLOGY TRANSFER

This section discusses the results of tests from a theoretical vapor control system implemented by the Environmental Protection Agency and its contractor, MSA Research Corporation.[1] The results of this system reported here reflect potential emission reductions from barge loading facilities should available technology become demonstrated in the future. In addition to engineering and safety considerations stated in Section 1, there are a number of nontechnical problems that need to be addressed before a vapor control recovery system is feasible.[2] For instance:

1. Retrofitting existing barges for vapor control systems may be particularly costly. Some estimates have put the figure at $110,000 per barge (1983 dollars).[3] Moreover, a particular control technique may have unique retrofit costs and it is unknown how this will affect barge retrofit applications. The

cost of retrofitting a barge has not been taken into account in the vapor system cost analysis.

2. In the case of a leased barge, the responsibility for installing a vapor system needs to be specified. Additionally, the beneficiary of any recovered gasoline needs to be determined.
3. The responsibility for installation and maintenance of safety equipment needs to be specified.
4. Additional training for barge and refinery facility operators may be necessary to familiarize themselves with the vapor systems.

The use of a vapor control recovery system from an undemonstrated technology transfer from gasoline bulk plants, may result in a reduction of VOC emissions by 85 percent or better. Table 4-1 presents estimated present emissions and potential emission reductions, should technology transfer become feasible.

4.2.1 Air Impacts

A model plant with gasoline throughputs ranging from 500 x 10^6 l/yr (3 x 10^6 bbls/yr) to 1,400 x 10^6 l/yr (9 x 10^6 bbls/yr) was chosen. This range of gasoline throughputs is representative of the range of capacities observed for gasoline barge loading facilities. The potential emission reductions are based on a vapor control system with control efficiencies of 95 percent for carbon adsorption, 87 percent for refrigeration, and 85 percent for lean-oil absorption. The efficiencies stated for carbon adsorption and refrigeration reflect midrange values of control efficiencies for gasoline reported in the literature.[4] This efficiency assumes the systems are properly sized and operated. No literature estimate of lean-oil absorption was found relating to barge loading facilities, so an efficiency of 85 percent was assumed.

4.2.2 Other Environmental Impacts

The use of an undemonstrated vapor control recovery system would be expected to have minimal impact on water and solid waste pollution, as well as a minimal impact on energy requirements.

TABLE 4-1. ANNUAL EMISSION ESTIMATES FOR VARIOUS GASOLINE THROUGHPUTS

Gasoline Throughput		Uncontrolled VOC Emissions[a]		Undemonstrated VOC Emissions[b]	
l/yr	bbls/yr	Mg/yr	tons/yr	Mg/yr	tons/yr
500×10^6	3×10^6	240	252	12	13
950×10^6	6×10^6	456	504	23	25
$1{,}400 \times 10^6$	9×10^6	672	756	34	38

[a]Calculated using an AP-42 emission factor of 0.00048 Mg/1000 l (4 lbs VOC/1,000 gal) gasoline and does not include dock estimates of 7 Mg/yr.

Sample calculation:

Gasoline Throughput: 500×10^6 l/yr

(gasoline throughput) uncontrolled emission factor (1 - control efficiency)

= Undemonstrated VOC Emissions

$$(500 \times 10^6 \text{ l/yr}) \frac{0.00048 \text{ Mg VOC}}{1{,}000 \text{ l}} (1 - 0.95) = \text{Mg VOC/yr}$$

[b]Undemonstrated emissions are based on operation of a vapor control recovery system with a vapor control efficiency of 95 percent for a carbon adsorption system and do not include dock emission estimates of 7 Mg/yr. This system has not been demonstrated in a permanent application.

4.3 REFERENCES

1. MSA Research Corporation. Demonstration of Vapor Control Technology for Gasoline Loading of Barges, EPA Contract No. 68-02-3141. December 1979.

2. Memorandum from Sink, M., Pacific Environmental Services, Inc. to Project File, PES Project No. 0727. Industry comments to PEDCo., Inc. report. April 1985.

3. PEDCo Environmental Inc., Vapor Controls for Barge Loading of Gasoline, EPA Contract No. 68-02-3512. December 1983.

4. D. Gee and W. Talbert, Control Technology Evaluation for Gasoline Loading at Barges. Pullman Kellogg, Houston, TX. EPA Contract No. 68-02-2619. March 1979.

5.0 CONTROL COST ANALYSIS OF RACT

For gasoline loading of barges, RACT is determined to be in place, hence there are no RACT cost implementations to analyze. Estimates of capital and annualized costs for undemonstrated control techniques are presented in Sections 5.1 and 5.2, respectively. These costs are based on 1979 dollars and updated to December 1984 through use of engineering cost indexes. The cost effectiveness of these systems is discussed in Section 5.3.

5.1 CAPITAL COSTS

The capital cost analysis focuses on the purchase and installation of a vapor control recovery system capable of handling a gasoline throughput of 950 x 10^6 l/yr. These costs reflect a fairly straightforward application of a vapor control system and do not include costs for barge modifications, ship-to-shore transfer arms, safety modules for the vapor control system, and any dock renovation necessary to install a system. The analysis does include vapor piping to the control unit. The costs not included will likely be the result of site specific conditions and are not taken into account in this discussion. Capital costs for barge modifications have been estimated at $110,000 per barge but have not been included in the cost analysis because:

1. It is unclear how many barges service a dock, hence, how many barges need modifying per dock site, and
2. Since no standard vapor control recovery system exists, it is difficult to estimate the actual costs of modifying a barge to fit a particular recovery technique.

Three systems have been investigated and all have control system efficiencies estimated at 85 percent or better. Table 5-1 gives the capital costs for carbon adsorption, lean-oil absorption, and refrigeration, respectively.

Lean-oil absorption is the least expensive of the three, having a total installed capital cost of $226,500, while carbon adsorption

Table 5-1. BASIS FOR TOTAL INSTALLED CAPITAL COSTS
(December 1984 dollars[a])

Cost Item \ Control Method	Activated Carbon	Lean-Oil Adsorption	Refrigeration
Purchased Equipment Cost			
Skid Mounted Unit	350,500[b]	151,200[b]	353,500[b]
Electric Feeder	3,500	6,540	6,500
Vapor Piping to Unit	13,100	13,100	13,100
Parts Inventory	4,000	4,000	4,000
Two Oil Tanks	N/A	19,000	N/A
12,000 gal #2 Oil	N/A	9,000	N/A
Freight	4,000	4,000	4,000
Taxes	11,250[c]	6,200[c]	11,430[c]
Installed Direct Cost			
Concrete Pad 18' x 30' x 4"[b]	3,500	3,500	3,500
Rigging, Crane, Men[b]	1,800	1,830	1,830
Site Preparation	3,700[c]	1,670[c]	3,900[c]
Indirect Costs			
Contingencies	11,250[c]	6,400[c]	11,430
TOTAL Costs	406,600	226,500	413,190

[a]Reference 2. Costs updated to December, 1984 dollars using factor of 1.31 = 324.2 (Dec. 1984)/247.6 (Dec. 1979).

[b]Reference 3.

[c]Reference 4. Taxes and contingencies are estimated as 3 percent of purchased equipment cost excluding taxes. Site preparation is estimated at approximately 1.1 percent of skid-mounted unit cost.

Note: loading rate for these systems is 4,200 gal/min.

costs are $406,600, and refrigeration are $413,190. The capital cost for lean-oil absorption is based on a unit that can handle only one barge a day (throughput of 950 x 10^6 l/yr), while the other two are capable of higher throughputs through consecutive barge loadings indefinitely with one or two hours lapse between loadings. If the lean-oil unit were sized as to be able to handle consecutive loadings, its capital costs would probably be comparable to the other two, but no cost data for a similar sized system were reported.

5.2 ANNUALIZED COSTS

Annualized costs for the vapor control recovery systems are presented in Table 5-2. The annualized costs include gasoline recovery credit which is valued at $110,000 for a carbon adsorption system, $101,000 for a refrigeration unit, and $98,000 for a lean-oil absorption unit. The annualized costs for the lean-oil absorption unit are less than the other two, for reasons previously stated. Otherwise, the annualized costs would be comparable to carbon adsorption and refrigeration. The estimated control efficiency for an activated carbon adsorption unit is 95 percent, which is a midrange value of efficiencies reported in the literature.[5] Similarly, a control efficiency of 87 percent was assumed for the refrigeration unit.[5] No reported literature values were found for the lean-oil system, hence an efficiency of 85 percent was assumed. All systems have been costed with a stripper unit to recover gasoline. An assumed stripper efficiency at 85 percent enables calculation of an overall recovery efficiency of 81 percent for carbon adsorption, 74 percent for refrigeration, and 72 percent for lean-oil absorption which represent the product of the efficiencies of the control unit and stripper unit. This means that in the case of carbon adsorption, for every 100 gallons of gasoline introduced into the control unit, 95 gallons will be adsorbed in the control unit of which 81 gallons will be recovered for resale in the stripper unit. No demonstrated vapor control system efficiency is available, therefore for purposes of cost comparisons between the control units, a 100 percent efficiency is assumed. This assumes that all vapors from the barge ducted to the control unit arrive intact; i.e., there are no system leaks to the atmosphere. Annualized costs do not include any necessary additional

TABLE 5-2. BASIS FOR NET ANNUALIZED COSTS
(December 1984 dollars)

	Activated Carbon	Lean-Oil Absorption	Refrigeration
Capital Recovery Cost[a]	53,300	29,800	54,130
Electricity[b]	7,800	7,380	7,800
Maintenance and Op. Labor[b]	11,800	12,000	19,600
General and Administrative[b]	10,900	7,410	12,150
Total Annual Costs	83,800	56,590	93,680
Product Recovery Credit[c]	(110,000)	(98,000)	(101,000)
Net Annualized Cost[d]	(26,200)	(41,410)	(7,320)

(xx) = Cost Savings

[a]Capital Recovery Cost calculated as product of Capital Recovery Factor (CRF) and Total Capital Costs. CRF calculated as:

$$\frac{i\,(1+i)^n}{(1+i)^n-1} = 13.1\%$$

where i = 10 percent
n = 15 years

[b]Reference 4.

[c]Assumed overall recovery efficiency based on product of control unit efficiency and stripper efficiency. Assumed throughput of 950×10^6 l/yr. Product recovery credit based on retail price of gasoline at $0.70/gallon. Calculation is based on carbon adsorption unit. Reference 6.

gasoline throughput x uncontrolled emissions x overall recovery efficiency x Product recovery value = Product Recovery Credit

$$\frac{950 \times 10^6\ \text{l}}{\text{yr}} \times \frac{0.00048\ \text{Mg}}{1000\ \text{l}} \times \frac{2202\ \text{lbs}}{1\ \text{Mg}} \times \frac{\text{gal}}{5.16\ \text{lbs}} \times 0.81 = 157{,}500\ \text{gal recovered}$$

$$157{,}500\ \text{gal} \times \frac{\$0.70}{\text{gal}} = \$110{,}000$$

note: (0.95 adsorber efficiency) x (0.85 stripper efficiency)
= 0.81 overall efficiency.

[d]Net Annualized Cost is the difference between Total Annual Costs and Product Recovery Credits.

materials, taxes or insurance, as these costs will tend to be dock specific.

5.3 COST EFFECTIVENESS

The cost effectiveness estimated to install and operate these systems represents the net annualized costs per emission reduction achieved. These costs do not include any estimate of a vapor control recovery system or barge modifications and are based solely on the cost of a control unit. The net annualized costs, given in Table 5-2, show that all units are quite cost effective. Again, the cost effectiveness of the lean-oil unit would be lower (less dollars per megagram controlled) if it were sized differently. Table 5-3 shows the actual cost effectiveness given in dollars per megagram of emissions controlled.

TABLE 5-3. COST EFFECTIVENESS
(December 1984 dollars)

	Activated Carbon Adsorption Unit	Lean-Oil Absorption	Refrigeration Unit
Net Annualized Costs[a]	(26,200)	(41,410)	(7,320)
Emission Reduction[b] (Mg/yr)	433	388	397
$/Mg VOC reduction[c]	(60)	(106)	(18)

(xx) = Cost Savings, i.e. the value of the recovered product exceeds the annualized costs expended on the vapor control unit.

[a]From Table 5-2. Does not include barge retrofit costs.

[b]Sample calculation for carbon adsorption: $456 \frac{Mg}{yr} \times 0.95 = 433$ Mg/yr emission reduction.

[c]Net annualized cost divided by annual emission reduction.

5.4 REFERENCES

1. PEDCo Environmental Inc., Vapor Controls for Barge Loading of Gasoline, EPA Contract No. 68-02-3512. December 1983.

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4. Neveril, R.B., Gard, Inc. Capital and Operating Costs of Selected Air Pollution Control Systems, U.S. Environmental Protection Agency, Research Triangle Park, NC. EPA-450/5-80-007. December 1978.

5. D. Gee and W. Talbert. Control Technology Evaluation for Gasoline Loading of Barges. Pullman Kellogg, Houston, TX. EPA Contract No. 68-02-2619. March 1979.

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